Landscape Dynamics Component: Physical Setting

Key Terms Used in This Section

Air Pollutants — Any substance in air that could, if in high enough concentration, harm humans, other animals, vegetation, or material. Air pollutants may include almost any natural or artificial matter capable of being airborne, in the form of solid particles, liquid droplets, gases, or a combination of these.

Air Quality — The composition of air with respect to quantities of pollution therein; used most frequently in connection with "standards" of maximum acceptable pollutant concentrations.

Coarse woody debris (CWD) — Woody material derived from tree limbs, boles, and roots in various stages of decay, larger than 3 inches (7.5 cm) in diameter.

Geologic processes — The actions or events that shape and control the distribution of materials, their states, and their morphology, within the interior and on the surface of the earth. Examples of geologic processes include: volcanism, glaciation, streamflow, metamorphism (partial melting of rocks), and landsliding.

Geomorphology — The geologic study of the shape and evolution of the earth's landforms.

Headwaters — Beginning of a watershed; unbranched tributaries of a stream.

Hydrologic — Refers to the properties, distribution, and effects of water. "Hydrology" refers to the broad science of the waters of the earth—their occurrence, circulation, distribution, chemical and physical properties, and their reaction with the environment.

Physiography — Pertaining to the study of the formation and evolution of landforms.

Sediment — Solid materials, both mineral and organic, in suspension or transported by water, gravity, ice, or air; may be moved and deposited away from their original position and eventually will settle to the bottom.

Soil organic matter — A variety of compounds derived from weathering and decomposition of plant residue. Organic matter within the litter layer or surface soil horizon is an important nutrient reservoir for maintaining soil productivity.

Soil productivity — The capacity of the soil to support plant growth, due to the physical and chemical characteristics of the soil including depth, temperature, water-holding capacity, and mineral, nutrient, and organic matter content.

Tectonic — Relating to, causing, or resulting from structural deformation of the earth's crust. An earthquake is an example of a type of tectonic process.

Watershed — 1) The region draining into a river, river system, or body of water. 2) In this EIS, the term watershed also refers specifically to a drainage area of approximately 50,000 to 100,000 acres, which is equivalent to a 5th-field Hydrologic Unit Code (HUC).

Summary of Conditions and Trends

Soils and Soil Productivity

- Soil productivity across the project area is generally stable to declining. Generally, greater declines in soil productivity are associated with greater intensities of vegetation management, roading, and grazing.
- Soil organic matter and coarse wood (woody material larger than three inches) have been lost or have decreased in many areas as a result of displacement and removal of soils and removal of whole trees and branches due to management activities.
- In wilderness, roadless, and other areas, high levels of coarse wood and organic matter have accumulated because of fire suppression and mortality resulting from insect and disease outbreaks.
- Soil material has been lost through direct displacement of soils and through surface and mass erosion. Erosion can result from changed water runoff patterns caused by increased soil exposure (such as from loss of biological crusts), soil compaction, and concentration of water from roads.
- Changes in the physical properties of soils have occurred in conjunction with activities that increase bulk density through compaction. These changes have largely resulted in impaired soil process and function, such as decreased porosity and infiltration and increased surface erosion.
- Sustainability of soil ecosystem function and process is at risk in areas where redistribution of nutrients has resulted from changes in vegetation composition and pattern, removal of larger wood, and risk of uncharacteristic fire.
- Floodplain and riparian area soils have reduced ability to store and regulate chemicals and water, in areas where riparian vegetation has been reduced or removed or where soil loss associated with roading in riparian areas has occurred. In these areas, water quantity may be reduced during low flows, and water quality may have less buffer from pollution.

Hydrology and Watershed Processes

- Management activities throughout watersheds in the project area have affected the processes of sedimentation and erosion and the production and distribution of organic material, thus affecting hydrologic conditions. On federally administered lands the most pronounced changes to watersheds are due to water diversions and impoundments, road construction, vegetation alteration (including silvicultural practices, fire exclusion, and forage production), and excessive livestock grazing pressure.
- Stream flow regimes have been locally affected by dams, diversions, and groundwater withdrawal. More subtle but widespread changes to natural stream flows on federally administered lands have probably been caused by road construction and changes in vegetation due to silvicultural practices and excessive livestock grazing pressure.
- The frequency and extent of seasonal floodplain and wetland flooding have been altered by changes in flow regime due to dams, diversions, and groundwater withdrawal, and by changes in channel geometry due to sedimentation, erosion, and channelization resulting from installment of transportation improvements such as roads and railroads.
- Banks and beds of streams, rivers, and lakes have been altered by bank and shore structures, including urban development, transportation improvements, instream mining activities, flood-control works, and alteration of riparian areas. In general, the changes have been greatest for the larger streams, rivers, and lakes.

Air Quality

- The current condition of air quality in the project area is considered good, relative to other areas of the country.
- Wildfires significantly affect the air resource. Current wildfires produce higher levels of smoke emissions than historically, because fuel available to be consumed by wildfire has increased.
- Within the project area, the current trend in prescribed fire use is expected to result in an increase of smoke emissions.

Introduction to Physical Setting

The template for current ecological conditions is the culmination of millions of years of geological, climatological, and ecological processes. This evolutionary history defines the capabilities of the naturally occurring land systems and provides a framework for limitations on how humans can use the varied terrains and resources of the project area. The material presented here focuses on those geologic, soil and hydrologic, climatological, and air quality issues that are relevant for ecosystem management at the broad scale. Much of the information in this section is derived from the Biophysical (Jensen et al. 1997), Landscape Dynamics (Hann, Jones, Karl, et al. 1997), and Aquatics (Lee et al. 1997) chapters of the *Assessment of Ecosystem Components* (Quigley and Arbelbide 1997); reports of the *Eastside Forest Ecosystem Health Assessment* (Everett et al. 1994); and additional sources as cited.

Geology and Physiography

Plate tectonics, volcanism, glaciation, weathering, erosion, and sedimentation processes over the past 1.5 billion years have resulted in the present mountain ranges, river courses, and watershed divides that characterize the project area.

These geologic and physiographic attributes exert considerable influence over climate, hydrology, and drainage pattern development. Surface topography and soils at the subwatershed scale were largely formed during the Pleistocene ice ages (1.6 million years ago). The physiography of individual channels and hillslopes is controlled primarily by recent (past 10,000 years) geomorphic processes and disturbances, such as floods, landslides, and volcanoes. The diversity of geologic environments, along with active tectonic, volcanic, and glacial processes, has been a controlling influence in the evolution and distribution of ecological systems, including patterns of human development and use.

The physiographic environment also dictates ecological potential and management options. For example, glaciated terrain commonly consists of steep slopes that are covered with highly erodible soils and glacial sediments; areas near volcanoes commonly have thick, ash-rich soils that are highly productive but are also susceptible to compaction.

Erosion, sediment transport, and deposition are the geologic processes most relevant in day-to-day management of ecosystems in the project area. Moreover, these processes have been significantly affected by human activities.

Soils and Soil Productivity

Background: Soil Processes, Functions, and Patterns

Much of the following material is summarized from the Biophysical chapter (Jensen et al. 1997) of the *Assessment of Ecosystem Components* (Quigley and Arbelbide 1997), Harvey et al. (1994), and Henjum et al. (1994).

Critical soil processes—such as nutrient cycling, infiltration, and percolation—occur in the upper few inches or feet of soil. Disruption of soils can lead to long-term changes in ecological conditions.

Soils form an ecologically rich and active zone at the interface between geologic materials and the atmosphere. The soil that occurs at a particular site depends on the geologic parent material, climate, relief, and organisms occurring at that site, and on the amount of time that has been available for these soil-forming factors to interact. Most soils in the project area are young and thin, and critical soil processes—such as nutrient cycling, infiltration, and percolation—occur in the upper few inches or feet. Soil-forming and soil-recovery processes can be slow; therefore, disruption of soils can lead to long-term changes in ecological conditions, including biological and hydrologic processes.

Soil regulates the cycling and availability of plant nutrients through the storage and movement of water and energy within the soil profile (Page-Dumroese

1991; Harvey et al. 1987 in Jensen et al. 1997). Soil anchors vegetation and contains mineral nutrients and water that provide the biological productivity, site stability, and ecosystem resiliency required for plant growth. Soils also contain a vast variety of microorganisms that promote decomposition of organic material, such as leaves, twigs, and large wood. This decomposition process is a critical link in the nutrient cycling process, especially for plant nutrients such as carbon, nitrogen, potassium, phosphorous, and sulfur (see Figures 2-3 and 2-4). The diverse geology and climate of the project area, in conjunction with natural and human disturbance, have resulted in a spatially complex pattern of soils that differ in appearance, function, and response to management activities.

Soil Horizons

Most soils in the ICBEMP project area have formed since the last ice age and are composed of several horizons, or layers. At the surface, there is commonly a thin (generally less than two inches) and sometimes discontinuous cover of decaying organic matter, such as leaves and twigs. Under this cover of litter and duff is a layer (less than a few inches) of dark, highly decomposed organic matter (humus) which covers a mineral layer of up to several feet thick. This mineral layer may contain organic matter, clay minerals, calcium carbonate, and other salts that are transported down the soil column by percolation or burrowing activities. These horizons have differing capacities for supplying nutrients and holding water. Because the highest concentration of nutrients and biota are in the uppermost soil horizons, incremental removals of surface soil (such as by soil erosion) are more damaging than removal of subsoils (Swanson et al. 1989 as cited in Jensen et al. 1997).

In general, forested environments have thicker and more continuous organic matter layers consisting of litter and duff material above the mineral soil compared to rangeland soil horizons. The thickness and amount of organic material varies considerably depending on local vegetation characteristics, climate, relief, and disturbance history (including human uses and fire). These soil horizons together cover weathered and unweathered parent materials, such as bedrock or old stream gravel. Volcanic material is a major component of many soils.

Physical Properties

Physical properties of soils, such as bulk density (dry weight per unit volume), porosity, texture, hydrologic conductivity, soil depth, and mineral content, are all factors controlling hydrologic response, water-holding capacity, and surface stability. Soil water-holding capacity is a critical factor in the project area where growing season precipitation is low. Soils with high organic matter contents generally have high porosities and high water-storage capacities but are susceptible to compaction.

The physical properties of soils can be altered by disturbances such as erosion and compaction. Soil compaction results from concentrated activity, including use of heavy equipment, vehicles, pedestrian activity, and excessive livestock grazing pressure. Where soils are compacted, porosity, permeability, and hydrologic conductivity are reduced, resulting in altered runoff patterns and increased surface erosion. Natural recovery of surface compaction can take 50 to 80 years, depending on the soil type, degree of compaction, frequency of freeze-thaw cycles, and input of organic matter. Recovery of compacted subsoils often requires up to 200 years.

Biological Properties

Soil biological properties also affect productivity. Soil is a reservoir of fungal spores and other organisms important for decomposition and nutrient cycling. These organisms are far more numerous than above-ground plants and animals (Molina and Amaranthus 1990), and their interactions profoundly affect forest site productivity through assimilation of nutrients, protection against disease organisms, maintenance of soil structure, and buffering against moisture stress (Amaranthus and Trappe 1993). Soil moisture and temperature strongly influence forest type, distribution, and soil productivity. Erosion or removal of soil surface layers, where most microorganisms reside and where most of the critical nutrient cycling processes occur, can significantly affect productivity for several decades.

Organic Matter

Organic matter, both above and below ground, is an important component for maintaining soil productivity. Organic matter is important for soil water retention, cation exchange, nutrient cycling, and erosion control (Page-Dumroese et al. 1991). In general, the higher the total soil organic matter, the higher the site productivity. Throughout most of the project area, decomposition of organic matter is often slow, leading to accumulations of surface organic matter. Reductions in soil productivity through the loss of organic matter can be caused by erosion of surface soils, damaging fires, and over-utilization. Management

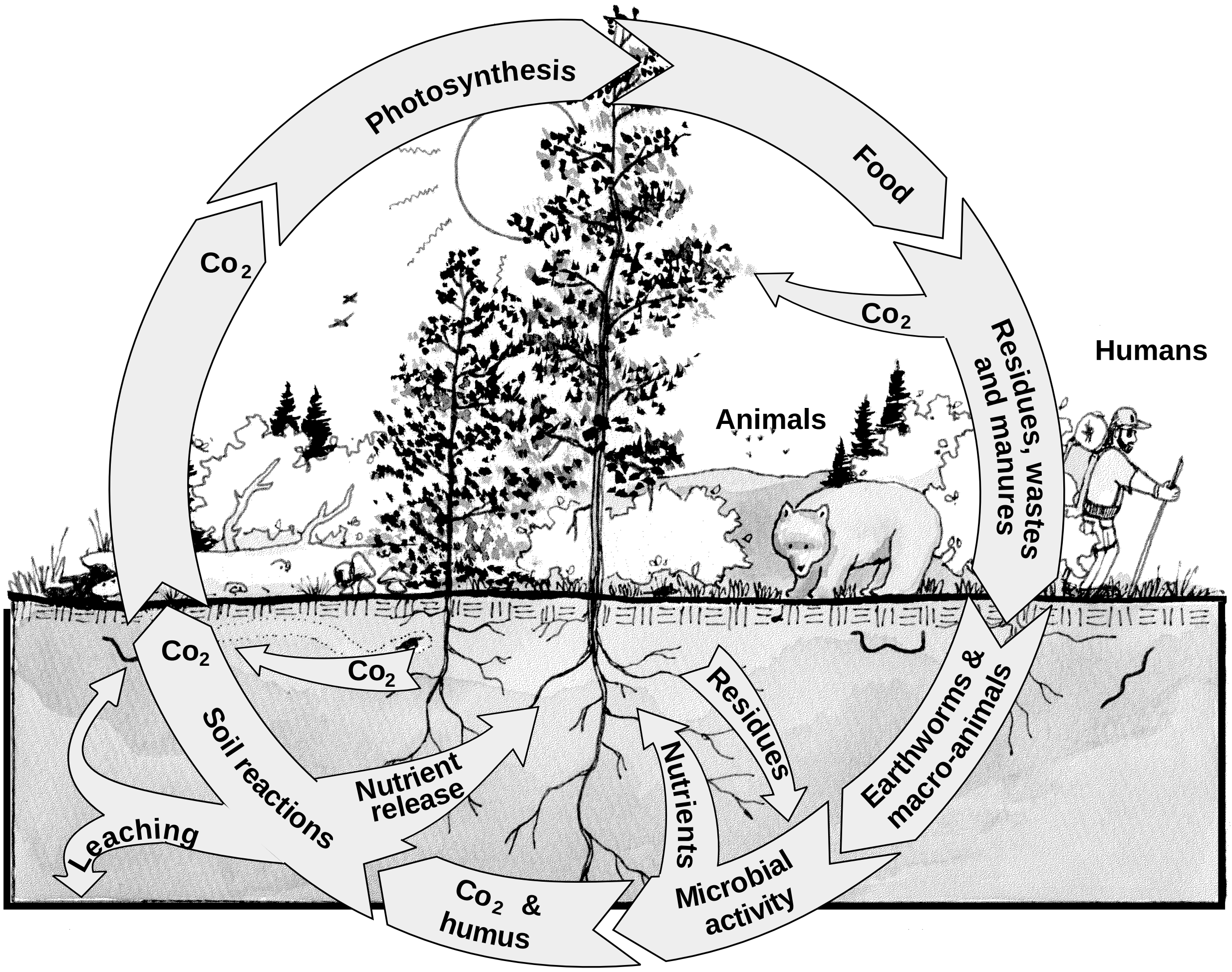

Figure 2-3. Carbon Cycle

Carbon is the key building block in all living cells. It is captured primarily through photosynthesis and stored in the form of plant tissues: needles, leaves, stems, twigs, branches, bark, roots, and wood fiber. Carbon also is diverted below ground to support soil organisms and processes. Carbon is recycled through several processes including respiration of plants and animals, fire, and decomposition by bacteria and fungi. The decomposition process is a critical link in the nutrient cycling process.

More carbon is now being accumulated and stored in the project area in denser stands of shade-tolerant, non-fire-adapted species. Insect and disease disturbance has increased and has begun to play a larger role in carbon recycling. As tree mortality increases, more carbon and nutrients are tied up in standing and downed dead woody material and in deep organic layers on the ground. Soil properties and soil-vegetation relationships also have been affected since many beneficial soil organisms depend on living trees to fuel their activities.

Changes to the carbon cycle can also affect other nutrient cycles such as the nitrogen cycle (see Figure 2-4) and can set the stage for widespread extreme wildfire events that further jeopardize many other ecosystem components and functions.

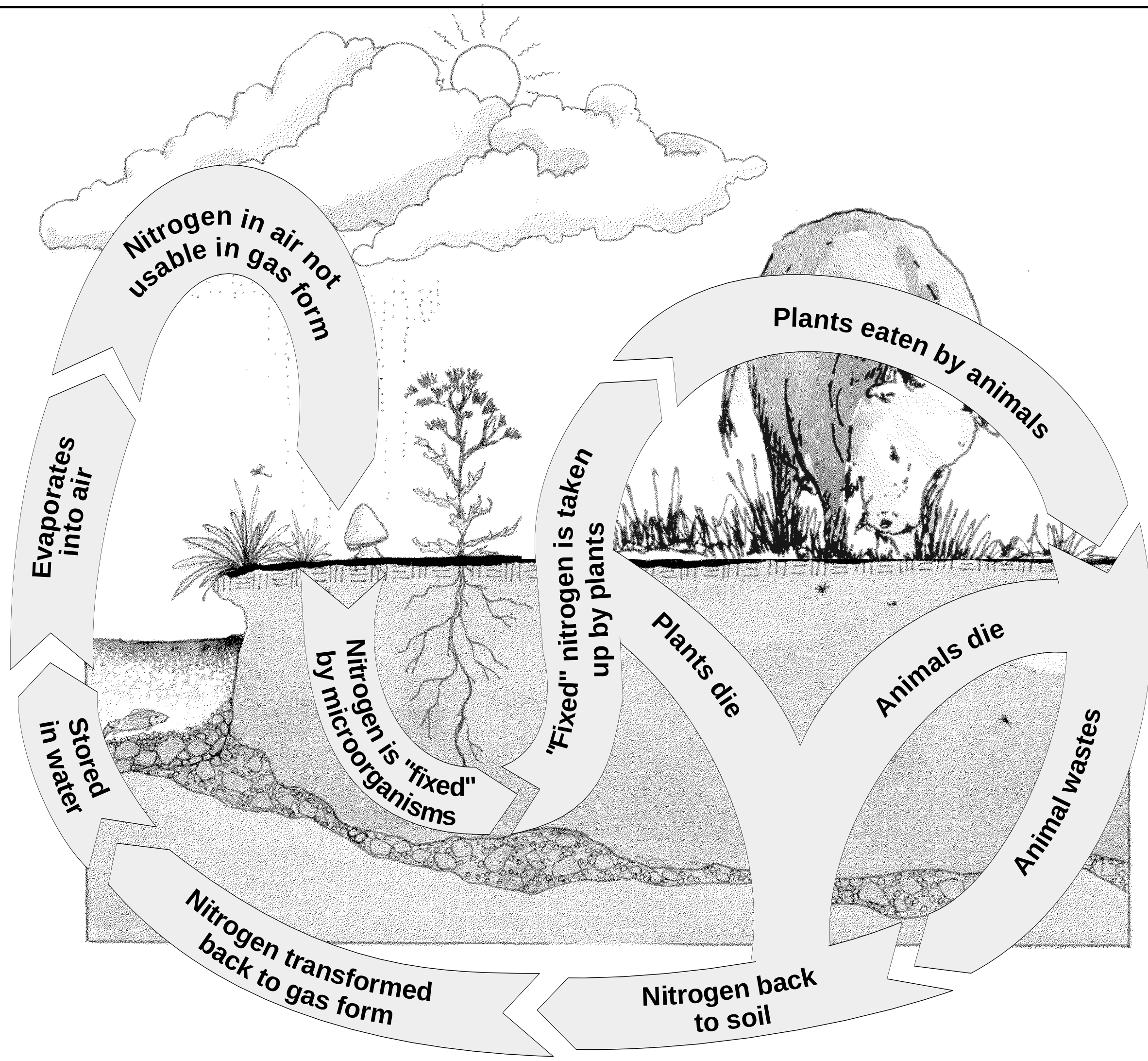

Figure 2-4. Nitrogen Cycle.

Nutrients such as nitrogen are essential for life. Nitrogen is circulated continually among plants, animals, and microorganisms. The amount of nitrogen available and the rate at which it cycles are important to ecosystem health.

Nitrogen in the air can't be used directly by plants and animals; it must be captured and transformed (or "fixed") by specific bacteria or algae into a usable form. Nitrogen-fixing organisms that live on the roots of certain plants change nitrogen gas into forms that can be used in biological processes. When plants and animals die, their bodies are decomposed by other microorganisms to return nitrogen to the air. The decomposition process is a critical link in the nutrient cycling process.

A close, interdependent relationship exists between nitrogen and carbon. The proportions of each element play an important role in regulating the decomposition rate of organic matter and in controlling the rate at which nitrogen and other nutrients are cycled. Factors that affect the nitrogen cycle will also have effects on the functioning of the carbon cycle (see Figure 2-3).

Soil erosion is one of the conditions in the project area that can contribute to reduction or loss of usable nitrogen, by reducing the total organic matter and thus the potential total nitrogen content of the soil. Another condition is the conversion of sites to monocultures of shallow-rooted (often exotic) species, which affects the depth to which plant roots can deposit nitrogen in the soil.

activities, especially those resulting in compaction from equipment or livestock use, can also lead to decreased soil productivity by reducing the availability of organic matter.

Fire

Accumulated litter and woody debris are potential fuel for wildfire, which is an important factor controlling soil conditions in forestlands and rangelands of the project area, especially in drier environments where fire frequency is high (Harvey et al. 1994). The combined processes of biological decomposition and fire regulate nutrient availability and cycling.

Fire can substantially change surface soil characteristics and rates and can influence patterns of vegetation on the landscape.

Fire can substantially change surface soil characteristics and erosion rates and can influence patterns of vegetation on the landscape. Fire can have consequences on soil productivity by consuming organic matter and vegetation. Nutrients, such as nitrogen, can be evaporated by fire, resulting in an immediate loss of soil productivity as well as limiting future inputs of nutrients. However, nutrients such as carbon are also made available by fire, especially by converting large woody debris into smaller, more readily decomposed material (Debano 1990). Forests in the inland West, including the project area, depend on a combination of biological and fire-decomposition processes to regulate nutrient availability and cycling (Harvey 1994).

Fire can also affect soil productivity by creating bare soil or hydrophobic (water-repelling) conditions that alter infiltration, runoff, and erosion processes. In general, the more soil heating that occurs, the greater the potential for water repellence. Dry, coarse-textured soils are most susceptible to becoming water-repellent, especially after high intensity, high severity fires.

Current Conditions and Trends: Soils and Soil Productivity

Overall, soil productivity across the interior Columbia Basin is stable or decreasing. Soil conditions are generally stable in wilderness areas, but in other locations soils are at varying levels of decreasing productivity depending on soil types and intensity of management. Determining the exact status of soil condition for any given area is difficult because of the lack of inventory and monitoring data. In general, greater declines in soil productivity are directly associated with greater loss of soil from erosion and displacement, loss of soil organic matter, changes in vegetation composition, removal of whole trees and branches, and increased bulk density from compaction. The causal factors for declining soil productivity include improper implementation of vegetation management activities, road construction and maintenance, and excessive livestock grazing pressure. More recently, large-scale, uncharacteristic wildfires have increased the number of landscapes with declining soil productivity through reduction in effective vegetative ground cover and loss of root strength, which has resulted in increased soil erosion rates.

Overall, soil productivity across the interior Columbia Basin is stable or decreasing.

Soil productivity may currently be higher in areas where fire has been suppressed and where organic matter and vegetation have not been removed. However, the unnaturally high amounts of vegetation and large woody material put these areas at risk for uncharacteristic fire intensity and severity, which can lead to decreased soil productivity because of high rates of erosion, loss of organic matter, woody material, and nutrient reservoirs.

Hydrology and Watershed Processes

Background: Watershed Hierarchies and Functions

Watersheds are natural divisions of the landscape and the basic functioning unit of hydrologic systems. Watersheds can be considered in a variety of scales ranging from continents to individual hillslopes or streams (Figure 2-5). Watersheds are hierarchical—smaller ones nest within larger ones. Commonly used terms referring to watershed scales are shown in Table 2-1a and illustrated in Figure 2- 1, both of which are found in the Introduction to this chapter.

Landforms contained within watersheds are also hierarchical. Valleys nest within watersheds, and their form is in part controlled by watershed physiography and geologic history. Streams and rivers flow through valleys, and channel form is influenced by interactions between streams and valleys. Individual features within channels, such as pools and riffles, reflect stream-channel processes and history, and as a result, are the culmination of watershed processes at multiple scales. These natural hierarchies make watersheds an appropriate context for considering many ecological processes.

Geoclimatic processes such as rainfall, erosion, and streamflow and sediment regimes commonly merge on a watershed basis to shape and form the landscape. Environmental changes in soil, vegetation, topography, and chemicals result in changes in the quantity and quality of water, sediment, and organic material that flow through a watershed. The response of a particular watershed to environmental change varies considerably because each watershed is unique. Factors that govern how a watershed may respond to environmental change include the size and location of these changes, the physical and biological characteristics of the watershed, and the history of natural and human disturbances.

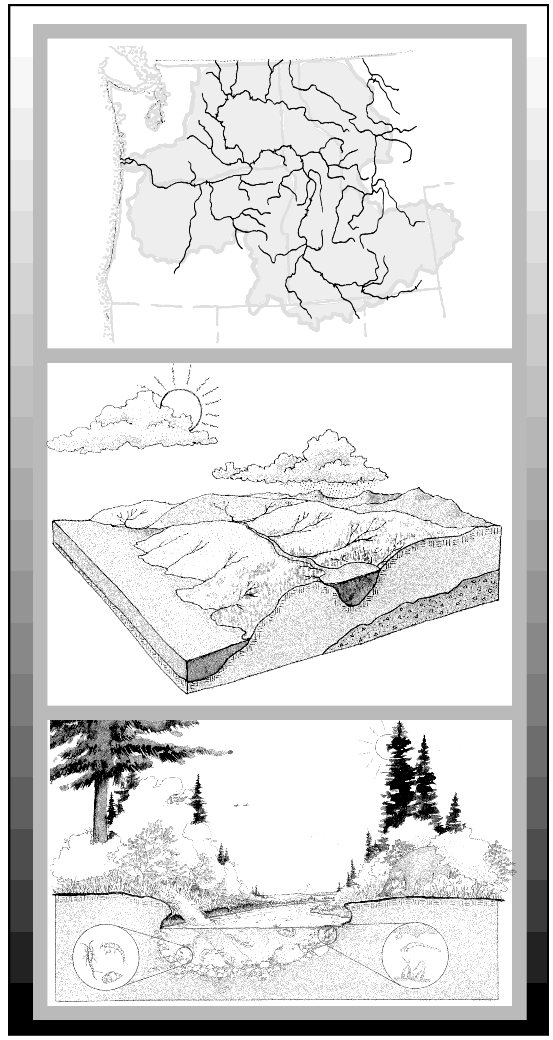

Figure 2-5. Ecosystem Scales. Watersheds and ecosystems can be considered on a variety of scales. The ICBEMP project focuses its attention on the broader scales illustrated in the top two boxes.

Background: Streams, Rivers, and Lakes

Movement of water is one of the fundamental ways to transfer energy and materials in ecosystems (Figure 2-6). Water in streams and rivers transports sediment, organic material, nutrients, and aquatic organisms, resulting in constant redistribution and shaping of landforms and stream channels. The wide variety of water bodies, with their associated energy and food sources, provide abundant and diverse habitats for water-dependent plant and animal species.

Stream flow regimes and water quality can be affected by modifications to watershed processes occurring from both natural disturbances and land management activities. A discussion on the current conditions of the physical characteristics of stream flow and water quantity in the project area is included in this section. Water quality, and water quantity effects on water quality, is a key component of riparian and aquatic habitats. Moreover, land managers have some degree of influence over the condition of aquatic ecosystems on Forest Service- or BLM-administered land through the management of water quality and quantity. Because of the water quality linkages to riparian and aquatic habitats, water quality is discussed in the Aquatic/Riparian section later in this chapter.

Streams, rivers, and lakes are a focus for human activities. As human population in the project area increases, and as demands for food, energy, transportation networks, and recreation opportunities expand, uses of stream and river systems increase. These uses have resulted and will continue to result in escalating conflicts over water and stream channels—not only among competing human uses but also between human uses and ecological requirements of the native biota.

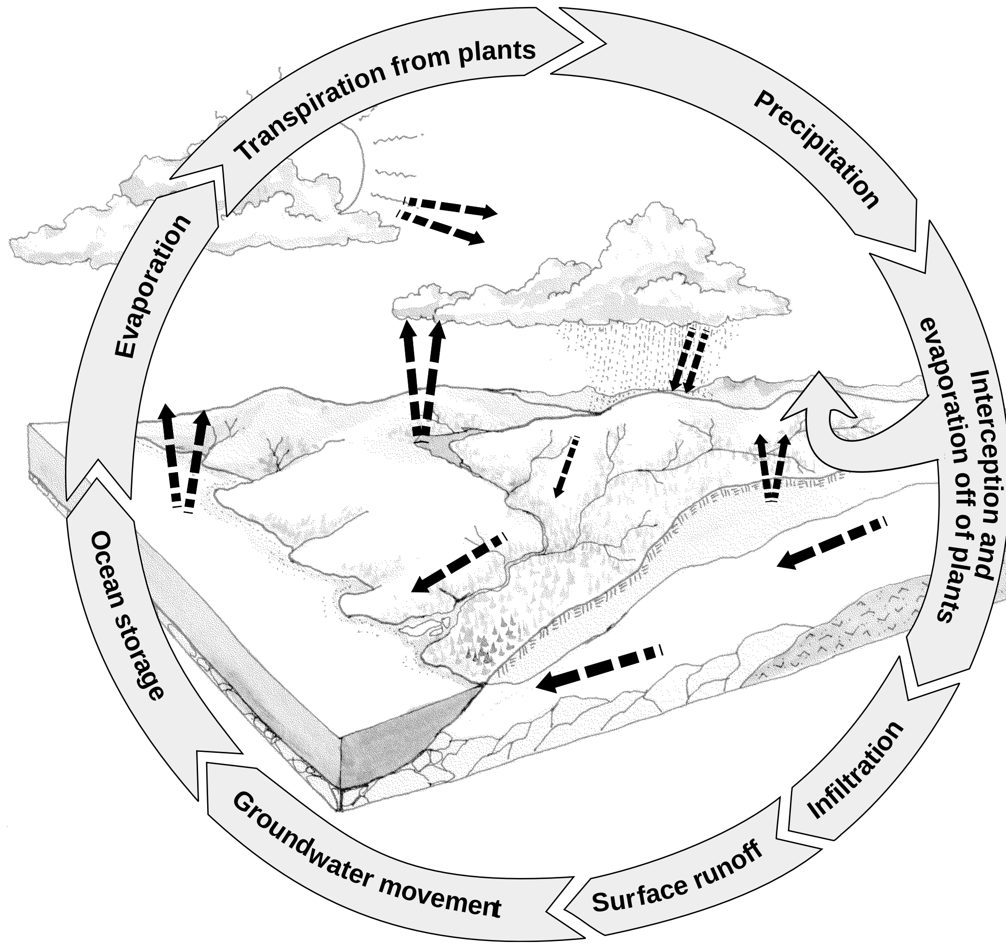

Figure 2-6. Hydrologic Cycle.

Movement of water is one of the fundamental ways to transfer energy and materials in ecosystems. The complex hydrologic cycle links water in the air, on the surface of the earth, and below ground. The interactions of the hydrologic cycle provide the key to processes (such as flooding) that route and deliver water, wood, and sediment to streams and connect the streams to their floodplains, adjacent riparian areas, and uplands. The wide variety of water bodies, with their associated energy and food sources, provide abundant and diverse habitats for water-dependent plant and animal species.

Stream flow regimes and water quality can be affected by modifications to watershed processes occurring from both natural disturbances and land management activities. Disturbance and compaction of soil and changes in vegetation also can alter hydrologic relationships in a number of ways, by changing: the way water infiltrates and is stored in the soil, how effectively groundwater is recharged, how much water evaporates to the air or is transpired through plants, how much and where surface runoff occurs, the amount and timing of streamflows, and the quality and quantity of water in lakes and streams. Such changes to these interactions and processes are tied inextricably to degradation of aquatic and riparian habitats for anadromous and inland fishes and terrestrial and aquatic wildlife.

Streams, rivers, and lakes also are a focus for human recreational, food, energy, transportation, and other activities. Many of these activities have resulted in further changes in the hydrologic cycle, and they play a role in escalating conflicts over water and stream channels—not only among competing human uses but also between human uses and ecological requirements of native plants and animals.

Stream Channel Processes, Functions, and Patterns

Water, sediment, solutes, and organic material derived from hillslopes and their vegetative cover flow into and through streams and rivers. The shape and character of stream channels constantly and sensitively adjust to the flow of these materials by adopting distinctive patterns such as pools-and-riffles, meanders, and braids (Leopold et al. 1964). The vast array of physical channel characteristics combined with energy and material flow, provides diverse habitats for a wide variety of aquatic and riparian-dependent species.

The varied topography within the project area, coupled with the irregular occurrence of channel-affecting processes and disturbance events such as fire, debris flows, landslides, volcanic activity, drought, and extreme floods, results in a mosaic of river and stream conditions that is dynamic in space and time under natural conditions (Reeves et al. 1995). The primary consequence of most of these disturbances is to directly or indirectly provide large pulses of sediment and wood into stream systems. As a result, most streams and rivers in the project area probably undergo cycles of channel change on a timescale ranging from years to hundreds of years in response to episodic inputs of wood and sediment. The types of disturbance, such as fire, flood, or debris flow, that affect the morphology of a particular channel depend on watershed characteristics, channel size, and position of the channel within the watershed (Reeves et al. 1995; Grant and Swanson 1995). Many aquatic and riparian plant and animal species have evolved in concert with the dynamic nature of stream channels; see the Aquatic Habitats section, later in this chapter, for details.

In order to guide understanding and management of streams and rivers, stream classification systems (such as Rosgen 1994; Montgomery and Buffington 1993) have been established on the basis of distinctive patterns of stream behavior. These classifications are primarily derived from consideration of stream slope and confinement (relating to the stream's ability to move and erode its banks and bed). In general, stream types range from steep and confined channels that generally consist of step-pool and cascade-dominated streams (Rosgen "A"; Montgomery and Buffington "source"); to moderate gradient and moderately confined rapid-dominated channels (Rosgen "B"; Montgomery and Buffington "transport"); to low gradient, unconfined, pool-and-riffle dominated channels (Rosgen "C, D, and E"; Montgomery and Buffington "response"). Other stream types include: gullied, or streams actively eroding their streambeds and streambanks (Rosgen "G") and low gradient, entrenched, wide streams (Rosgen "F").

In general, steeper channels (slopes greater than four percent) are commonly found in the headwater or mountainous portions of a landscape, and are less sensitive to watershed disturbances because of their high degree of confinement and their position high in the watershed unless the soils are highly erosive (Figure 2-7). Once disturbed, however, steep and confined streams may take considerable time to recover to their previous condition. Channels with slopes between two and four percent generally contain abundant rapids and steep riffles.

Lower-gradient streams (slopes less than two percent) are generally larger, and under natural conditions they meander and migrate freely within wider valleys (Figure 2-8). Low gradient streams and rivers commonly have numerous side channels and high water channels and generally contain the most biologically productive aquatic ecosystems. These low-gradient channels are generally sensitive to cumulative and local watershed disturbances, but they have the ability to recover quickly when natural hydrologic and sediment regimes are present.

Stream Flow Regimes and Water Quantity

Within the interior Columbia Basin, there are approximately 254,700 miles of streams and rivers (including larger irrigation canals) and several thousand lakes mapped at the scale of 1:100,000. Most of the lakes are small (surface areas smaller than 12 acres) and are at high elevations (higher than 5,000 feet). Forty-nine percent of these streams and a majority of the lakes are on Forest Service- or BLM-administered lands.

Most of the streams ultimately drain into the Columbia River, which has a drainage area of 237,000 square miles (152 million acres) and an average annual discharge of 140 million acre feet at the town of The Dalles, Oregon. About 35 percent of the flow at The Dalles originates from Canada. A large part of the flow from the southeastern portion of the project area enters the Columbia River via the Snake River, which has a drainage area of 108,500 square miles (69 million acres) and an average annual discharge of 40 million acre feet near its confluence with the Columbia River in south-central Washington.

Most surface runoff results from snowfall and / or rainfall in mountainous regions, resulting in spring and summer annual peak discharges. Most streamflow in the project area results from surface runoff or shallow groundwater flow into streams. The vast majority of streamflow originates on public lands, especially higher elevation Forest Service-administered lands. A few streams, however, in the volcanic provinces of the Columbia Plateau, Upper Klamath Basin, Northern Cascades, and Southern Cascades ERUs have significant components of inflow from ground-water. Groundwater-influenced streams provide unique terrestrial and aquatic habitats because of their relatively constant flows of cold, clear, and high-quality water. In eastern Oregon and Washington, elevations below 2,000 feet, including most BLM-administered lands, usually do not contribute significantly to streamflow (Wissmar et al. 1994). There is substantial year-to-year variability in streamflow quantity because of variability in rainfall and snowfall accumulation (McIntosh et al. 1994).

Road construction in forested environments probably has the largest effect on runoff and streamflow, although most studies investigating this issue have been outside the project area. Relatively impermeable road surfaces combined with cutbanks, fill-slopes, and roadside ditches result in decreased infiltration and increased rates of surface runoff. Roadcuts intercept subsurface flow while roadside ditches and newly formed gullies downstream from culverts extend the stream network, creating a channel system that is highly efficient in delivering surface runoff and sediments to stream channels (Harr et al. 1975, 1979; Megahan et al. 1992; Jones and Grant 1996; Wemple 1994; Ziemer 1981). Also see the discussions on roads in the economic and social considerations section and elsewhere in this chapter.

Vegetation manipulation activities can change rates and amounts of evaporation and transpiration (water use by plants), and, in some areas, can change rates and volumes of snow accumulation and snowfall. These effects are best understood for forested environ-

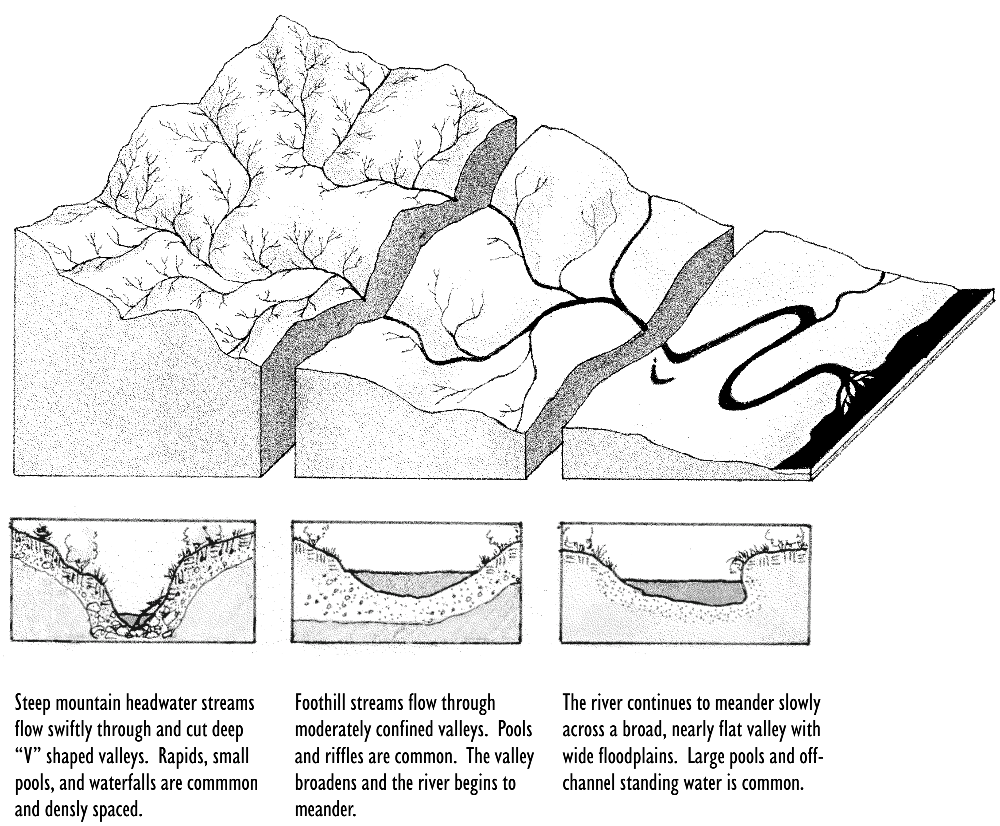

Figure 2-7. Steep Mountain Headwaters Profile. Stream channels change in shape and velocity based on the steepness of the round slope and the amount of surface water. In general, steeper channels are commonly found in the headwater or mountainous portions of a landscape. These may be less sensitive to watershed disturbances, yet once disturbed they may be slow to recover.

ments, where, within clearcuts, snow tends to accumulate in greater amounts and melt faster than in forested areas, leading to larger and earlier peak flows (Harr 1986, King 1994). These effects are greatest in association with rain-on-snow events, during which rain falls on snowpack, causing melting and changes in the timing of runoff. This happens particularly within the "transient snow zone" found at elevations commonly between 2,000 and 5,000 feet. Although there is less clearcutting now, the hydrologic effects of past clearcuts can persist for three to four decades, depending on vegetation characteristics (FEMAT 1993). Soil compaction due to excessive livestock grazing pressure (Platts 1991), and timber harvesting activities, such as yarding and heavy equipment operation, can also result in decreased soil permeability and increased runoff (Chamberlin et al. 1991).

Current Conditions and Trends: Hydrology and Watershed Processes

Within the ICBEMP project area, humans have extensively altered stream channels by direct modifications such as channelization, wood removal, diversion, and dam-building, and also by indirectly affecting the incidence, frequency, and magnitude of disturbance events. This has affected inputs and outputs of sediment, water, and vegetation. These factors have combined to cause pervasive changes in channel conditions throughout the project area, resulting in aquatic and riparian habitat conditions much different from those that existed prior to

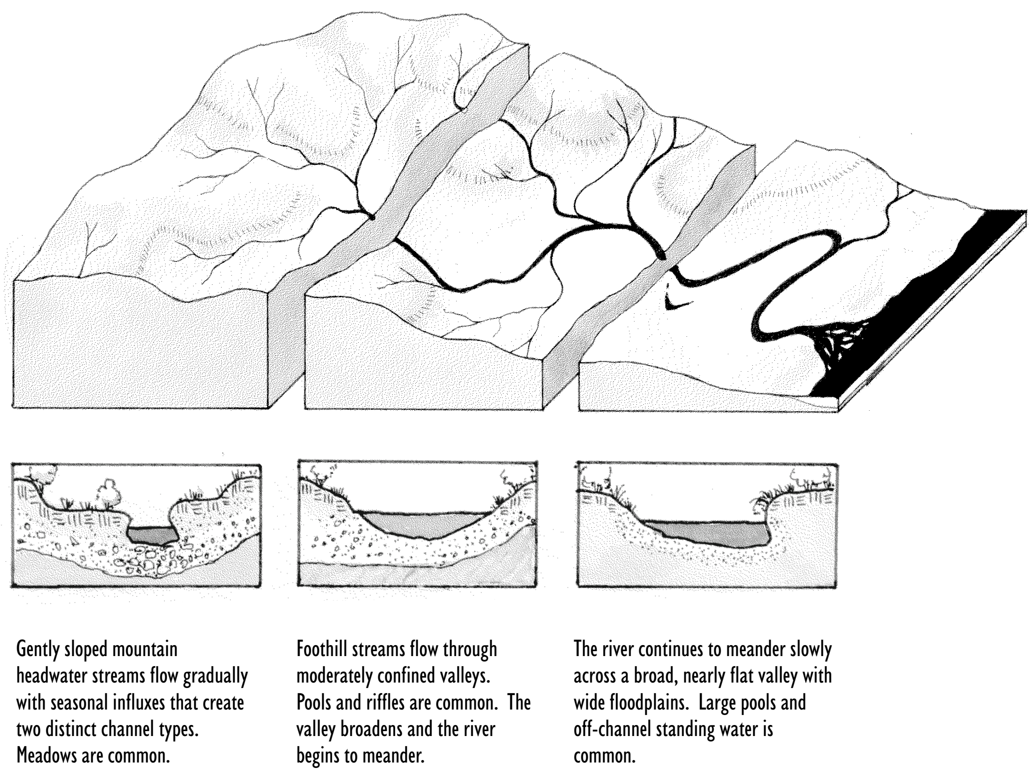

Figure 2-8. Lower Elevation Headwaters Profile. Lower elevation headwater streams flow more slowly and create distinct channel types different from steep mountain headwater streams. Once the streams reach middle and lower gradients, the stream profile resembles that of the stream whose headwaters started in steeper mountains. Lower gradient streams generally contain the most biologically productive aquatic ecosystems and are generally sensitive to cumulative and local watershed disturbances.

Photo #7

Not available in PDF.

More than 250,000 miles of streams and rivers of all sizes are found in the interior Columbia River basin.

extensive human alteration (Henjum et al. 1994; McIntosh et al. 1994; Wissmar et al. 1994). In general, the largest rivers, such as the Columbia and Snake rivers, have been converted from free flowing streams to a series of reservoirs. Many intermediate-sized rivers, such as the Payette, Clarks Fork, Clearwater, Grande Ronde, and Deschutes rivers, are now important transportation corridors that are flanked by roads, railroads, or both. Urban and agricultural areas, and other human structures and activities, now encroach upon their adjacent floodplains.

Pervasive changes in channel conditions throughout the project area have resulted in aquatic and riparian habitat conditions much different from those that existed prior to extensive human alteration.

Indirect effects of past land management activities are also pervasive in the project area. Mining, timber harvest, excessive livestock grazing pressure, homesteading, beaver trapping, and road-building have all altered channels by affecting the rate with which sediment, water, and wood enter and are transported through stream channels. Almost all Forest Service- or BLM-administered lands within the project area have experienced some level of resource extraction since the early 1800s. Most of the large-scale and intense operations that seriously affected channel morphology, such as in-stream dredging and overgrazing, were halted by the early 1900s (Wissmar et al. 1994). Nevertheless, the effects of past management activities clearly continue to affect channel morphology today.

Within the project area, lake conditions have been most affected by recreation and residential development. Recreation activities such as backpacking, horsepacking, recreational vehicle use, and road and trail development have resulted in damage to lake environments, particularly beaches and other near-shore areas. Recreation activities have commonly led to introduction of non-native plant and animal species, resulting in local extinction of native invertebrates, amphibians, and fish. Recreational boating has led to the introduction of numerous non-native plants, such as Eurasian watermilfoil. Large mid-elevation lakes, such as Priest and Payette lakes in Idaho, Flathead Lake in Montana, and Klamath Lake in central Oregon have been the most affected from a growing regional population seeking to live or recreate near lakes.

Water transfers and diversions for drinking water or irrigation water supply have affected and continue to affect many lakes throughout the project area, especially where drought and diversion of inflow have resulted in very low lake levels during the past several years. Dozens of moderate-sized lakes have their shorelines influenced by modification and control of their outlet streams or rivers. Regulation of lake level for water supply purposes has had effects on near-shore aquatic and wetland plant and animal communities, and on the spawning success of near-shore spawning fishes. Additionally, inter-basin water transfers have promoted the continued spread of non-native plants and animals while inhibiting natural migration routes of native species.

On Forest Service- or BLM-administered lands, management activities that have altered flow include impoundments (dams and reservoirs), water withdrawal (diversions and pumping), road construction, and vegetation manipulation. Timber harvest, fire suppression, excessive livestock grazing pressure, and associated activities have altered the timing and volume of streamflow by changing on-site hydrologic processes (Keppeler and Ziemer 1990; Wright et al. 1990). These changes are either short or long term depending on which hydrologic processes are altered and the intensity of alteration (Harr 1983).

Scarcity of streamflow during the growing season, year-to-year streamflow variability, and the general aridity of low-elevation valleys and plains have spurred flow regulation and storage, water diversions, and groundwater withdrawal throughout the project area for irrigation, livestock tanks, flood control, hydropower, and recreation. In total, about seven million acres in the Columbia River Basin are presently irrigated, resulting in a seven to ten percent reduction of annual flow volume (Hann, Jones, Karl, et al. 1997). As a result of impoundments and diversions, most streams in the project area, especially larger ones, have significantly altered flow regimes. Consequently, habitat conditions have changed, especially for those aquatic species that have survival strategies adapted to natural flow patterns (see Aquatic Habitats section, later in this chapter). Altered flow regimes also affect channel stability by changing the rates and timing of sediment and organic-material transport. For a discussion of habitat fragmentation see Lee et al. (1997); see Jensen et al. (1997) for a discussion of streamflow variability and the integrity of hydrologic processes.

The past history of fire suppression also may have affected water quantity and quality. On rangelands, fire suppression is partly responsible for expansion of western juniper. Expansion of western juniper and increasing density can result in decreased understory vegetation (Hann, Jones, Karl, et al. 1997), which is believed to contribute to decreased soil infiltration and increased peak discharges during intense rainfall. In forested environments, increased aboveground vegetation due to fire suppression may also have resulted in increased evapotranspiration rates and decreased runoff. Where high intensity fires have increased due to fire suppression, soil porosity has decreased, thus increasing runoff and soil erosion. Fire can also cause water-repellent layers to form in soils, resulting in temporarily increased runoff (DeBano et al. 1976).

Climate

The varied topography and geographic position of the project area (relative to global ocean and atmospheric circulation patterns) result in very different climates. The climate, in turn, strongly influences ecological processes such as biological productivity, fire regime, soils, streamflow, erosion, and human uses of the land and resources. For a discussion see Jensen et al. (1997); Hann, Jones, Karl, et al. (1997); Ferguson (1998); and Ferguson (1999).

Precipitation and Temperature

Most precipitation in the project area falls in the winter when eastward moving storms enter the area. Typically, more than 80 percent of the annual precipitation falls from October to May. Expansion of the North Pacific high pressure system in the early summer effectively blocks the flow of moisture into the Pacific Northwest, resulting in generally stable, warm, and dry summers. The Cascade Range separates eastern Oregon and Washington from the maritime climate west of it, leaving the interior Columbia River Basin with a continental climate of cold winters and warm, dry summers. Map 2-3 shows the annual precipitation patterns for the project area.

Average annual precipitation ranges from more than 100 inches per year at the crest of the Cascade Range to less than 8 inches per year in the low-elevation basins and plains.

Average annual precipitation ranges from more than 100 inches per year at the crest of the Cascade Range to less than 8 inches per year in the low-elevation basins and plains. Substantial portions of the project area, especially rangelands, receive less than 12 inches of precipitation per year. In these areas, recovery of vegetation and soil from human and natural disturbance takes place much more slowly than in areas with greater rainfall. The highest precipitation is in the mountain ranges, notably the Cascade Range, the Blue Mountains, the central Idaho Mountains, and the Northern Rocky Mountains. Most precipitation falls during winter and accumulates as snow, with mean annual snowfall of 100 to 200 inches along the crest of the Cascade Range and in the Blue Mountains. Spring, summer, and fall storms provide growing season rainfall in the mountains, especially in the eastern part of the project area.

The project area experiences a wide range of temperature variation. High mountainous areas have cold winters and short, cool summers with growing

Map 2-3. Annual Precipitation.

seasons that are locally less than 30 days in the highest alpine areas. Intermontane valleys and plateaus have cool to cold winters and hot summers, resulting in growing seasons that exceed 150 to 200 days in parts of the Columbia Plateau.

Drought

Drought is defined as an absence of usual precipitation (less than 75 percent of normal), for a long enough period that there is decreased soil moisture and stream flow, thereby affecting ecological processes and human activities. All regions experience temporary, irregularly recurring drought conditions, but dry climates generally are affected most (Barry and Chorley 1982). Year-to-year climate variability generally increases with aridity. In areas with average annual precipitation of less than 12 inches, drought years occur 20 to 40 percent of the time.

Drought affects fire and rangeland management. Dry years, such as 1988 and 1994, commonly result in widespread wildfire in forested environments, especially if there have been several preceding dry years. Drought significantly reduces forage production on rangelands, which can lead to degradation of upland and riparian areas if livestock grazing is not properly managed (Vallentine 1990). Drought can also increase the susceptibility of forestlands to insect infestation. The regional drought of 1920 to 1940 in the Pacific Northwest created substantial insect infestation problems, particularly for pine species (Agee 1994).

Climate Change

Climate change is not a new phenomenon in the project area. Changing climates through time have resulted in continuing adjustments by aquatic and terrestrial ecosystems. Changes in temperature and precipitation have direct impacts, such as effects on the efficiency of photosynthesis and length of growing season; they also have indirect effects, such as alterations in fire and flood frequency. Past climate change in the project area has ranged from global-scale changes (such as the transition between glacial and interglacial periods approximately 10,000 years ago, which resulted in about a ten degree Fahrenheit increase in mean annual temperature) to smaller yet still important changes (such as the period of generally cooler temperatures that began approximately 4,000 years ago and culminated in the Little Ice Age of the 1700s and early 1800s). Over the past several decades in the Pacific Northwest and globally, there has been significant warming (one to three degrees Fahrenheit) that some scientists have attributed to increased carbon dioxide emissions and the greenhouse effect.

Vegetation is especially sensitive to climate change. Upper and lower forest boundaries in the project area have shifted up and down in elevation by hundreds of feet during the past several centuries in response to temperature changes of one to three degrees Fahrenheit (Mehringer 1995; Neitzel et al. 1991). In general, plants on the fringes of their distributions respond most sensitively and rapidly to climate change. Within the project area, such changes are expected to continue to greatly influence the area and extent of vegetation types, especially changes in elevation of the overlapping conifer and steppe communities (Mehringer 1995). Vegetation responds to climate change in different directions and at different rates, reassembling in new and sometimes unpredictable associations that are constantly changing (Graham and Grimm 1990).

Air Quality

Background

Air quality in the project area was not pristine before it was settled by Europeans in the 1800s. Smoke from wildland fires has occurred in project area ecosystems for thousands of years.

Air quality in the project area was not pristine before it was settled by Europeans in the 1800s, particularly with regard to smoke. Many historical accounts refer to the presence of smoke and burned areas in the interior Columbia Basin, the Harney Basin, near the mouth of the Umatilla River, on the western slope of the Blue Mountains, and along the section of the Oregon Trail from the juncture of the Boise and Snake Rivers to the Columbia River (Robbins and Wolf 1994). Levels of smoke declined as fire was excluded from forests, particularly after the advent of organized fire suppression in the 1930s. Brown and Bradshaw (1994) concluded that levels of smoke in the Bitterroot Valley, Montana, were 1.3 times greater prior to settlement in the 1800s than they have been recently. Agee (1993) documents that fire has played a role as a disturbance agent in the development of Pacific Northwest ecosystems.

Emissions from wildland fires have occurred in project area ecosystems for thousands of years. For example, layers of charcoal found in the Sheep Mountain Bog near Missoula, Montana, and the Williams Lake Fen north of Cheney, Washington, provide evidence of wildland fire at varying intervals from 10,000 years ago to the present (Johnson et al. 1994). Fires from as long as 4,000 years ago are evident from charcoal found at Blue Lake, near Lewiston, Idaho. Several sites show significantly increased levels of charcoal starting about 1,000 years ago, attributed to burning by Native Americans.

Current Conditions

Conditions Related to the Clean Air Act

The Clean Air Act, passed in 1955 by the Congress and amended several times, is the primary legal instrument for air resource management. The Clean Air Act requires the Environmental Protection Agency (EPA) to, among other things, identify and publish a list of common air pollutants that could endanger public health or welfare. These commonly encountered pollutants, referred to as "criteria pollutants," are listed by the EPA along with the results of studies documenting the health effects of various concentrations of each pollutant. For each criteria pollutant, the EPA has designated a concentration level above which the pollutant would endanger public health or welfare. These levels are called the National Ambient Air Quality Standards (NAAQSs).

To date, NAAQSs have been established for six criteria pollutants: sulfur dioxide ($S0_2$), particulate matter (PM_{10} and $PM_{2.5}$), carbon monoxide (CO), ozone (O_3), nitrogen oxides (No_x), and lead (Pb). There are exceptions, but generally these standards are not to be violated anywhere the public has free access within the United States. If NAAQSs are violated in an area, the area is designated as a "non-attainment area," and the state is required to develop an implementation plan to bring it back into compliance with these standards. To help protect air quality, the Clean Air Act (Section 118) requires federal agencies to comply with all federal, state, and local air pollution requirements. Class 1 airsheds and non-attainment areas are shown in Map 2-4.

Pollutants such as oxides of nitrogen and sulfur are of concern to federal land managers because of their potential to cause adverse effects on plant life, water quality, and visibility. However, the sources of these pollutants are generally associated with urbanization and industrialization rather than with natural resource management activities. Therefore, these pollutants will not be considered further in this EIS. On the other hand, particulates, carbon monoxide, and ozone are criteria pollutants that can be created by fire; these pollutants are discussed here. The pollutant of greatest concern for management activities in the project area is particulate matter (PM).

Three elements of the Clean Air Act generally apply to management activities that produce emissions in the project area:

1. Protection of National Ambient Air Quality Standards (Section 109);
2. Conformity with State Implementation Plans (Section 176(c)); and
3. Protection of Visibility in Class I Areas (Section 169A).

Protection of National Ambient Air Quality Standards (NAAQSs)

Particulate matter produced by land management activities or natural events on federally administered lands originates from wildfire, prescribed burning, road or wind-blown dust, volcanic eruptions, construction, mining, and vehicle use. However, most particulate matter of concern is produced from fire, and most of this is *less* than 10 micrometers (PM_{10}) in diameter, which is the size class that is regulated.

Because fire and smoke are a natural part of forestland and rangeland ecosystems, PM_{10} produced from fire does not seriously affect these ecosystems. However, it does have effects on human health. PM_{10} particles can be drawn deep into the alveolar region of the lungs, the part of the respiratory system most sensitive to chemical injury (Morgan 1989 in Sandberg and Dost 1990). Wood smoke also contains carcinogenic compounds.

Ozone is a photochemical pollutant formed on warm sunny days from nitrogen dioxide and hydrocarbon emissions, which are byproducts of burning. The chemistry of ozone formation is poorly understood; however, it is known that ozone is present in the smoke plume downwind of large fires. However, smoke plumes that do not rise (and therefore are likely to be encountered by humans) generally result from low intensity fires, which have much lower emissions of ozone. Also, the occurrence of fires is generally dispersed geographically and over time. Therefore, there is little risk to human health from exposure to ozone resulting from fire. Because fire is

Map 2-4. Class I Airsheds and PM_{10} Non-attainment Areas.

Photo by Karen Wattenmaker.

Smoke emissions from fires can stay suspended in the air for many miles, potentially affecting air quality.

a natural event within forestland and rangeland areas, to some extent ozone produced by fire is also a natural event, and these ecosystems have some natural adaptation to its effects.

Carbon monoxide is generated mainly by incomplete combustion of carbon. There have been few, if any, measured effects to the ecosystem from carbon monoxide. It is generated during wildland burning but is rapidly diluted at short distances from a fire and, therefore, poses little or no risk to community health (Sandberg and Dost 1990). However, carbon monoxide can be a health concern for firefighters on the fireline depending on concentration, duration, and level of activity (USDA Forest Service and John Hopkins University 1989).

Many *other* non-criteria, but potentially toxic, pollutants are emitted by wildland fire, including polynuclear aromatic hydrocarbons (sometimes referred to as PAHs) and aldehydes. Effects on human health vary by levels of exposure to these pollutants emitted during combustion. Some polynuclear aromatic hydrocarbons are known to be potential cancer-causing agents; other components, such as aldehydes, are acute irritants. Many of these air toxics dissipate or bind with other chemicals soon after release, making it difficult to estimate human exposure and consequential health effects. Additionally, the health and welfare effects of air toxics released by prescribed burning or wildfires have not been directly studied.

Conformity with State Implementation Plans

Non-attainment areas are those that have violated National Ambient Air Quality Standards. None of the national forests or BLM districts in the project area lie within non-attainment areas.

The Clean Air Act requires each state to develop, adopt, and implement a State Implementation Plan to ensure that the NAAQSs are attained and maintained for the criteria pollutants. These plans must contain schedules for developing and implementing air quality programs and regulations. State Implementation Plans also contain additional regulations for areas that have violated one or more of the NAAQSs (non-attainment areas).

The general conformity provisions of the Clean Air Act (Section 176(c)), prohibit federal agencies from taking any action *within a non-attainment area* that causes or contributes to a new violation of the NAAQSs, increases the frequency or severity of an existing violation, or delays the timely attainment of a standard. Federal agencies are required to ensure that their actions conform to applicable State Implementation Plans. The Environmental Protection Agency developed and finalized criteria and procedures for demonstrating and ensuring conformity of federal actions to State Implementation Plans. However, as written, they apply only to federal actions that occur within non-attainment areas.

As of the printing of this EIS, none of the national forests or BLM districts in the project area lie within non-attainment areas. Therefore, requirements of the conformity regulations do not apply to management actions proposed in this EIS. However, federal actions must still comply with State Implementation Plans.

Protection of Visibility in Class I Areas

Congress, in the Clean Air Act, declared as a national goal "the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Class I federal areas when the impairment results from manmade air pollution". Class I areas in the project area include wilderness areas of at least 5,000 acres or national parks of at least 6,000 acres that were in existence prior to 1977. Clean Air Act amendments have also enabled tribes to classify areas as Class I areas. Map 2-4 shows the federal Class I areas in the project area.

To assure protection of visibility in Class I areas, the states of Oregon and Washington have adopted visibility protection plans as part of their State Implementation Plans, which dictate when and how much burning can take place. The State Implementation Plans for Idaho and Montana do not include visibility protection plans.

Class I areas are subject to the most limiting restrictions regarding how much additional pollution can be added to the air. Fine particulate matter, generally less than 2.5 microns in diameter ($PM_{2.5}$), is the primary cause of visibility impairment. Emissions from prescribed burning, which stay suspended for many miles, are in the 0.1 to 2.5 micron size class and generally reduce visibility.

Visibility was monitored and documented for many of the Class I areas in Oregon and Washington from 1983 to 1992 (Boutcher 1994). The study shows that visibility has improved in and around Class I wildernesses areas west of the Cascade Range, and it has remained stable east of the Cascades. This can be attributed to a reduction in prescribed burning and to Oregon and Washington State Implementation Plans. Comparable data and studies are not available for the remainder of the project area.

Results of a 1990 National Park Service study of visibility in national parks and wilderness areas in the Washington Cascade Range (Malm et al. 1994) indicated that burning vegetation contributed approximately 17 percent of the visibility impairment found in the study area, with 53 percent from sulfates, 9 percent from nitrates, and 20 percent from soil and other causes. These parks are on the western edge of the project area, but information on particle composition and source regions is relevant to the project area because these fine particles are transported over long distances. While the emissions that affected the Park Service study came primarily from industrial and urban emissions in the Puget Sound region, it is logical to expect that in the project area, emissions from land management activities would account for a larger proportion of particulates.

Managing Emissions From Prescribed Fire

Under the Clean Air Act, state and local governments and American Indian tribes have the authority to adopt their own air quality rules and regulations. These rules are incorporated into their State Implementation Plans if they are equal to, or more protective than, federal requirements. For example, Montana, Oregon, and Washington have officially adopted smoke management programs into their State Implementation Plans. In parts of Idaho, memoranda of understanding have been signed by the states and federal land managers establishing parameters for managing emissions from prescribed burning.

Tracking Emissions

An emissions information system is used in Oregon, Washington, Montana, and northern Idaho to quantify prescribed fire emissions and to track changes in emission productions within their jurisdictions. Federal land managers have an obligation to complete smoke management reports and apply appropriate mitigation measures to reduce potential impacts on air quality (EPA 1992). Managers use, although they are not limited too, available computer software to estimate fuel consumption, emissions, and smoke dispersion from prescribed burns.

Monitoring Air Quality

Several different monitoring networks currently measure air quality in the project area. The most extensive of these are the State and Local Air Monitoring Stations / National Air Monitoring Stations. Operated by the states, this monitoring network is used to determine whether the National Ambient Air Quality Standards are met. Monitors in this network are concentrated in population centers.

Federal agencies also operate monitors at five sites within or near the project area. These monitoring sites measure particulates and changes in visibility, using filters that can be analyzed to determine the relative contribution of different sources of particulate matter. In addition to monitoring pollutant concentrations, state and federal agencies collect and archive the following types of data about prescribed fires: location, acres burned, moisture content of fuels, tons to be consumed, and emissions to be released.